Article

Recovering Sicilian Silk Heritage through Digital Technologies: The Case of Piraino's Collection

Georgia Lo Cicero [1], **Valeria Seidita** [2], **Maurizio Vitella** [1], **Ester Alba** [3], **Mar Gaitán** [3], **Jorge Sebastián** [3], **Marcos Fernández** [4] and **Cristina Portalés** [4,*]

1 Dipartimento di Culture e Società, Università Degli Studi di Palermo, Viale Delle Scienze Edificio 15, 90128 Palermo, Italy
2 Dipartimento di Ingegneria, Università Degli Studi di Palermo, Viale Delle Scienze Edificio 7, 90128 Palermo, Italy
3 Department of Art History, Faculty of Geography and History, Universitat de València, Av. Blasco Ibáñez, 28, 46010 Valencia, Spain
4 Institute of Robotics and Information and Communication Technologies (IRTIC), Universitat de València, Av. de Blasco Ibáñez, 13, 46010 València, Spain
* Correspondence: cristina.portales@uv.es

Abstract: Textile conservation has given rise to small and medium-sized museums, usually with scarce resources. In Sicily, the little evidence that remains of silk production and opulent imports by the rich and powerful local aristocracy is kept in museums, parishes, and other cultural institutions. The documentation, dissemination, and enhancement of such a fragile heritage is today possible by means of technological tools that provide novel means to preserve, analyze, and exploit digital information. In this paper, we present some outcomes of the SILKNOW project, a project that applies computing research to the needs of diverse users (museums, educational institutions, the tourism industry, creative industries, media, etc.) and preserves the tangible and intangible heritage associated with silk. We show the methodology followed to build end users' needs into the Virtual Loom, a tool that deals with the 3D reconstruction of silk fabrics at the yarn level. We also provide a real example of how to integrate it at the museum level, specifically, at Piraino's Collection. The results demonstrate how small and medium-sized museums can access tools that will help them to carry out their daily tasks.

Keywords: silk fabrics; cultural heritage; museums; Virtual Loom; interdisciplinary work

1. Introduction

In cultural heritage, textile conservation [1–5] is often kept in small and medium-sized museums that lack opportunities and resources to transfer the importance of the heritage they treasure to society. Nevertheless, silk remains a living heritage that is part of the craft traditions of the major Mediterranean cities that participated in the cultural and technological innovations communicated through the Silk Road and, like Italy, were the gateway to Europe. Far from being a heritage that only belongs to the historical past and is related to the artistic and aesthetic tastes of our ancestors, silk is still alive in small family businesses that struggle to survive. They have an important link with this spectacular past as they are custodians of significant know-how and innovations applied to textile design that sometimes refer to the aesthetic formulas of the past [6].

The documentation, dissemination, and enhancement of such a fragile heritage is of utmost importance. Technological tools provide researchers with novel means to preserve, analyze, and exploit digital information; every day, new initiatives are materializing this symbiosis between technology and SSH (social sciences and humanities). For instance, virtual tours to visualize and navigate through heritage sites,

3D models to document the shape of artifacts, and augmented representations of heritage sites have all been explored in recent years [7–11]. Not only the materials/artifacts themselves, but also the representation of immaterial heritage is possible with new technologies: crafts, techniques, rituals, and other past events can be simulated and disseminated through interactive videos, virtual worlds, and other mixed reality experiences [12].

SILKNOW is an EU-funded research project that improves the understanding, conservation, and dissemination of European silk heritage from the 15th to the 19th century. It applies advanced computing research to the needs of diverse users (museums, educational institutions, the tourism industry, creative industries, media, etc.), and preserves the tangible and intangible heritage associated with silk [13,14]. In this paper, we will focus on some of the main results of this project applied to a small Sicilian collection and demonstrate through this case study how this experience can be extrapolated to other silk collections around the world.

Outcomes of the project to be addressed include the Virtual Loom, a software tool to reproduce 3D models of textiles following traditional weaving techniques, such as damask, lampas, or espolín. This tool has been introduced before in research papers [15–17], but the methodology followed in order to embrace end users' needs with the tool has not been explained before, something that we aim to address in this paper. To that end, in the first stage of the project, experts in art history, textiles, and cultural heritage defined a set of personas, i.e., specific profiles related to target audiences. Afterwards, they defined a set of functionalities for the tool that were relevant to the personas, and these were implemented by software developers. In this paper, we will show how this process works and explain how the Virtual Loom and other results from the SILKNOW project can be useful for museums by providing a real example of a Sicilian silk textile collection and dealing with the "museum director" persona.

The Virtual Loom is integrated in ADASilk (Advanced Data Analysis for Silk heritage), an exploratory search engine built on top of SILKNOW's knowledge graph that contains fabric entries with images and other information (e.g., production place, production timespan, material, technique). Specifically, ADASilk collects metadata and images about silk fabrics from various museums and represents them using a common model, the CIDOC-CRM (Conceptual Reference Model) ontology, that creates a knowledge graph [17,18]. In this paper, we will show the first steps towards integrating museum collections in ADASilk.

Therefore, the aim of this research paper is threefold: (1) to present some results of the SILKNOW project, specifically focusing on the interdisciplinary work to embed users' needs in the functionalities of the technological solutions; (2) to transfer research outcomes to the museum by presenting a pilot study involving a real environment and the "museum director" persona, and making use of the mentioned technological solutions; and (3) to demonstrate that these tools can be extrapolated to other silk collections which are or can be digitized. Aims 2 and 3 are the contributions of the current research, while the first aim is part of the methodology that we have followed.

This paper is structured as follows: Section 2 is dedicated to the state of the art, from museum labs and digital technologies to Sicilian silk heritage and Piraino's collection. Section 3 is dedicated to the Materials and Methods, where we explain the functionalities of the Virtual Loom and ADASilk, the two tools that have been applied to this collection. In this section, to explain functionalities, we also identify a set of personas and sectors, focusing on the "museum director" persona. In Section 4, we show the results of applying these tools to a specific collection, and in Section 5, we describe how museum collections can be integrated in the project web search engine. Finally, we provide some conclusions and directions for further work.

2. State of the Art

2.1. Digital Technologies and Museum Labs

SILKNOW intends, firstly, to preserve, protect, and disseminate silk heritage as well as its values. It also aims to preserve historical weaving techniques and their designs to serve both as heritage knowledge and as a channel of innovation [19] for today's creative and cultural industries. This will facilitate the development of a knowledgeable society built on a clear cultural base that will thus become a source of innovation and competitiveness and promote the use of new resources while also contributing to the development of the textile industry.

As the literature shows [20–22], technology has proved to be widely accepted in the conservation, dissemination, and protection of cultural heritage. It is often used in small museums, furnished with smaller budgets and, in many cases, dependent on local governments. Digital technologies can offer solutions at affordable costs [23].

These experiences of applying creativity, technology, and heritage can be traced to museums such as the Victoria and Albert, Manchester Art Gallery, Musée des Arts Decoratifs (France), Museo Nacional de Artes Decorativas (Spain), or the Iparművészeti Múzeum (Hungary) [24–26], whose collections are based on the importance of historical design for economic, social, and cultural innovation. The museum as a permanent laboratory has been one of the constants of some museums dedicated to design or craft collections, particularly ceramics. In this sense, SILKNOW's main idea is the understanding of silk history as a collective memory of all European countries and, therefore, part of a shared European identity. For this reason, its perspective is broad and embraces the values defended by the Council of Europe for cultural itineraries, understanding silk culture as an integral history of the industrial age, with its forms of life and its associated values [27].

This rationale is endorsed by many museums that escape the traditional conception of the museum. It is especially significant in contemporary art museums, but also in museums whose main objective is to safeguard a living and intangible heritage linked to design or craft processes in their different dimensions. As creative spaces appear in museums [28], the concept of the MuseLab emerges, i.e., a small laboratory created around principles of design thinking and proposals for emergence and opening. The MuseLab is truly a space for experimentation and practice for the sake of learning, innovation, and discovery. Although this museum logic escapes the conventional museum, some museums, such as the Prado Museum (Spain), have generated environments such as the MediaLab (today in Matadero, Madrid) which is conceived as a citizen laboratory for the production, research, and dissemination of social and cultural projects. It explores forms of experimentation and collaborative learning that have emerged from digital networks [29]. The Fab Foundation fosters makerspaces and FabLabs designed as innovation centers, especially applied to contemporary creativity, where design is an integral part. The objective of these spaces is "to educate, innovate and invent using technology and digital fabrication to allow anyone to make (almost) anything, and thereby creating opportunities to improve lives and livelihoods around the world" [30], while MuseLabs do not specifically revolve around technology or innovation, but rather around museality, possibility, and experimentation [31].

In the field of silk heritage, a few examples come to mind. In Europe, the model of the Fondazione Lisio stands out. It is an old silk factory founded by Giuseppe Lisio in Firenze in 1906 that has developed an interesting educational and cultural laboratory in order to keep alive the manufacturing heritage and the art of hand weaving silk, gold, and silver [32]. Regarding work shared among universities, textile companies, museums, and cultural heritage authorities, mention should be made of the Swiss project SilkMemory, linked to the Lucerne School of Art and Design. The result of the project is a web portal with textile sources from the Zurich silk industry [33] that features a number of filters and research tools. Together with selected visual sources from the database, it brings new users and value to textile artifacts [34].

2.2. Sicilian Silk Collections

In Sicily, a land of conquest and meeting place of various civilizations and rich cultures, little evidence remains of its past silk production or the opulent imports by the rich and powerful local aristocracy. They favored the arrival and production of fine textiles on the island [35,36], keeping up to date with the fashions of the moment from the earliest times of the great families, such as the Branciforte, to times closer to our own, where taste was directed and cultivated by the great and powerful bourgeois dynasties such as the Florios.

This evidence is preserved in museums, parishes, and other Sicilian cultural institutions and requires specific care. Indeed, silk textiles are particularly delicate and need to be preserved in the best possible way; silk is an organic substance and suffers damage from prolonged exposure to light and physical stress. Almost all the textile artifacts that have managed to survive the ravages of time are garments or trousseaus intended for liturgical use, made for this purpose from rich textiles or by assembling civil textiles. The latter are very rare, compared with ecclesiastical examples, because they were often dispersed with family inheritances, lost their value with changing fashions, were modified for re-use or even destroyed. On the other hand, the sacred garments used for Catholic worship are also symbolic and devotional objects, which is why they are kept in the treasuries of the most important churches and diocesan museums.

These collections are generally very rare and are often placed in the most varied museum contexts, not enjoying the specific attention they deserve. Information about these collections is neither interoperable nor standardized. In order to take a snapshot of the situation of textiles in Europe and to produce best practice guidelines, the SILKNOW project organized a series of workshops with the aim of helping these heritage institutions to access the digital arena. In Italy, the workshop was held on 25 February 2021. The participants represented nine Italian museums, three of them, Sicilian ones: the Diocesan Museum of Caltanissetta, the Diocesan Museum of Cuneo, the Diocesan Museum of Monreale, the Archdiocesan Museum 'G. Boccanera' of Camerino, the Diocesan Museum of Genoa, the Basilica San Sebastiano Museum of Acireale, the Diocesan Museum of Massa Carrara–Pontremoli, the Diocesan Museum of Padua, and the Diocesan Museum of Reggio Calabria.

The participants agreed about many points of discussion, and they emphasized the fact that cataloging is an essential tool for the preservation of artifacts and, above all, a valuable aid in encapsulating the essential information for reconstructing the history of the work under examination. Catalog records have been particularly helpful after catastrophic events such as earthquakes and floods. Precisely for this reason, they must be constantly updated, but this requires a professional within the museum system who has the specific knowledge of the various weaving techniques, can place them in each time period, and recognize manufacturers and their locations.

There is therefore a common need to constantly train cataloguers, conservators, and documentalists, but also to train the staff of parishes because very often they are the custodians of most ecclesiastical textiles or other donations, such as wedding dresses or other precious clothes. Most diocesan museums also use a common cataloging system organized by the CEI (Italian Episcopal Conference) and sponsored by the Soprintendenza per i beni culturali ecclesiastici e gli edifici storici, a system that is, however, closed in a restricted circuit. It was therefore agreed on that there is a need for a new inventory that integrates the CEI catalog with the shared knowledge of all textile museums for a fruitful exchange of local experiences using common guidelines and a specific vocabulary. In this regard, the use of tools such as a shared thesaurus was promoted, and this was one of the pivotal tools produced by the SILKNOW project. In fact, sharing historical and technical information is the basis of cultural and scientific dissemination and is beneficial for the proper preservation of the work. Finally, there was agreement on the need to share information with the users of museum collections in order to rediscover the close link between the textile artifact and the environment surrounding it, strengthening their mutual ties.

2.3. From the Museum to Digital Technologies: Piraino's Collection

The experience of the workshop served to broaden the horizon of the usability of the tools created during the project. We wanted to apply the experience of these instruments to an exceptional but little-known reality in Palermo, namely the Fondazione Museo del Costume Raffaello Piraino [37]. This renowned university professor and artist from Palermo has dedicated thirty years to collecting valuable clothes and accessories, and the collection has also been studied by the Superintendency of Cultural Heritage. His foundation is dedicated to important cultural activities and has participated in national and international exhibitions for the dissemination of the history of costume and fashion in Sicily, from the 1700s to the first half of the 1900s [38].

This collection is constantly growing thanks to continuous acquisitions and donations. It has more than five thousand pieces covering a time span from 1700 to 1950, building a narrative path of Sicilian fashion that goes as far as important families such as the Lampedusa of the Leopard and the Florios, who became legendary for the magnificence of the clothes they flaunted at social events.

Some objects in the collection are depicted in Figure 1. It shows a selection of gala dresses on display for a recent exhibition held at the museum.

Figure 1. Raffaello Piraino's collection.

In the following sections we will introduce the SILKNOW tools and how we used the Piraino collection as a case study.

3. Methodology

3.1. Definition of Personas

As mentioned above, the SILKNOW project was conceived primarily for the preservation and dissemination of knowledge about silk heritage. At the same time, it represents a breeding ground for activities and innovations in the creative and cultural industries. Therefore, during the first phase of the project's development, several activities were carried out to identify the users and the functionalities of the tools to be developed.

Regarding the users, we identified a set of personas [39,40]. The project partners collaborated according to the standard activities required in the software analysis phase [41,42]. We began by analyzing the project specifications and used the following questions as a guide to identify these profiles or personas:

- Which user groups are supported by the system to perform their work?
- Which user groups execute the system's main functions?
- Which user groups perform secondary functions, such as maintenance and administration?
- What external hardware or software system will the system interact with?

In addition, the Universitat de València team prepared a survey that was distributed online [43] from September to October 2018. The survey included questions to identify information about users, such as personal data and knowledge about silk heritage, in order to learn their previous experience and interest in the topic. Most of the responses came from Spain, Italy, and France, mainly from academic educational circles and the creative industries. They provided a well-defined picture of the typical users who inspired the personas used as references.

The interviewed art, textile, and cultural heritage experts led to a set of personas that represented specific profiles for each of the project's target audiences. The cultural heritage audience was one of the main target groups of the project. The following personas were identified for this audience: collector, museum curator, fashionista, middle-aged museum visitor, staff member of international organization, and museum director.

Afterwards, scenarios and functionalities for the project's software tools were defined. We started by describing the type of interaction each persona would have with the tool. One realistic scenario was created for each persona, taking the form of a textual, narrative description that focused on who performs certain actions with a particular tool and how the tool responds to them. Writing each scenario was useful to refine the identified persona.

3.2. SILKNOW's Tool Functionalities

The Virtual Loom is a tool that embeds historical weaves (every particular style or manner of interlacing threads passing in one direction with others giving them a concrete angle [44]) and weaving techniques (techniques used in the manufacture of a fabric or textile, such as clothing, rugs, tapestries, etc., which are based on the interlacing of textile fibers [45]) to produce 3D fabric representations. Detailed information on the fabric-related technical aspects considered in the Virtual Loom is available in [15].

Silk fabrics have specific characteristics: they are nearly flat objects and very fragile. The documentation of their visual appearance has traditionally been performed by means of imaging devices (e.g., RGB cameras, digital microscopes). However, only the surface of the object is documented with these devices, so the complex internal structure composed of a variety of yarns and their interlacing remains undocumented. To deal with this, in the Virtual Loom we produced 3D models of silk fabrics at the yarn level, taking as input data the minimum information of an image, the one usually available in textile digital collections. Its graphical user interface is highly intuitive, guiding users through the process

and making it possible for them to produce the models without any previous knowledge of historical textiles and/or weaving techniques. The Virtual Loom has been developed following an iterative process in which the comments and suggestions of partners and experts belonging to the SSH were especially relevant regarding the proper integration of weaves and weaving techniques, among other issues previously described in [46]. As a result, several versions of the tool are accessible from [47] (standalone) and from [48] (web version).

The functionalities related to the Virtual Loom, and the related personas and sectors, are shown in Table 1. As can be seen, the specific functionalities identified as especially relevant for the persona "museum director" are F03, F04, and F06, and these are further described. F08 and F09 also take into consideration every persona described for the CH audience, including "museum director".

Table 1. List of the functionalities that the Virtual Loom fulfills and their relation to personas and sectors.

General Functionality	Func. ID	Description of the Functionality (Additional Comments)	Personas	Sectors
Having access to a more personalized experience	F01	Being able to change the original design (for instance, by cropping the image)	Textile designer; CEO of a 3D printing company	Creative industries
	F02	Being able to weave a fabric on the basis of arbitrary images (users may want to weave designs not collected in ADASilk)	Textile designer; CEO of a 3D printing company; Journalist	Creative industries; Media
	F03	Being able to change the weaving technique (for instance, if a given design can be woven using different techniques)	Fashion student; Museum director	Research and education
	F04	Being able to change the weave	Museum director	Research and Education
	F05	Being able to change the colors of yarns	Textile designer	Creative industries
	F06	Being able to define the number of yarns	Museum director	Research and education
	F07	Being able to choose the resolution of the 3D model	Textile designer; CEO of a 3D printing company	Creative industries
	F08	Choosing the language (at least the ones addressed in SILKNOW: Spanish, French, Italian, and English)	All	All
Visualization	F09	Using a zoom tool for visualization of the 3D model	All	All

	F10	Visualizing on a map the section of the fabric that is being inspected	Textile designer	Creative industries
	F11	Being able to rotate the 3D model	Textile designer; CEO of a 3D printing company; Teacher	Creative industries; Research and education
	F12	Being able to visualize individual yarns on the 3D model	Teacher	Research and education
	F13	Being able to restore some damaged designs with the help of a mirroring function	ICOM Conservation Committee employee; All	Research and education; Cultural heritage and leisure
Download/ Export	F14	Downloading the subtracted designs from fabrics in vector format for reuse in graphic or product design, decoration, etc. (for instance, to reuse a decorative pattern or motif)	Textile designer; CEO of a 3D printing company	Creative industries
	F15	Downloading visualizations (bitmaps) of the resulting 3D model	ICOM Conservation Committee employee; CEO of a 3D printing company; Visually impaired tourist	Cultural heritage and leisure; Creative industries; Tourism
	F16	Downloading a 3D model of the weaving techniques presented by the Virtual Loom	Fashion student; CEO of a 3D printing company; Visually impaired tourist	Research and education; Creative industries; Tourism

Functionality F03. Six different weaving techniques can be selected in the Image Processing Tab of the Virtual Loom. These techniques are (Figure 2): Damask / Self-patterned; Espolín; Espolín with Damassé ground; Lampas; Damassé with metallic weft; Freestyle. Depending on the technique, different options are available in the Virtual Loom (number of yarns, weaves, etc.), and the resulting 3D model will be different. Figure 3 shows examples produced for different weaving techniques based on the same input image and using two yarns. It is worth noting that only two zones (one for the background and one for the design) are considered in the three examples of Figure 3 so that they can be easily compared.
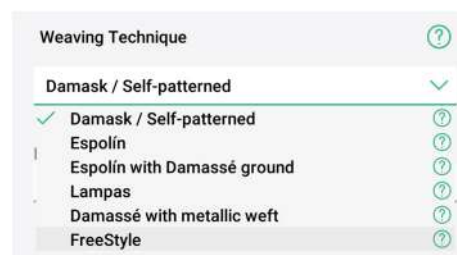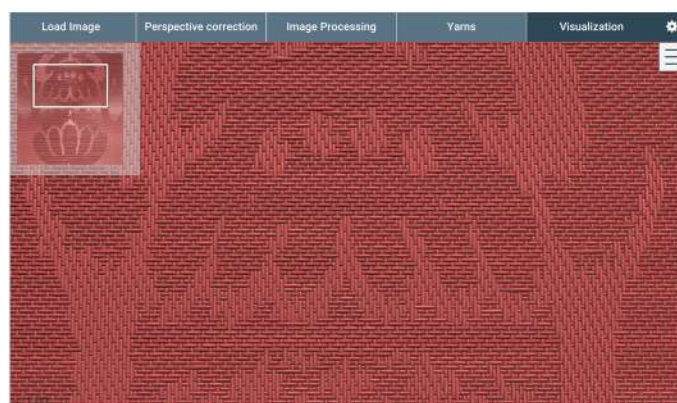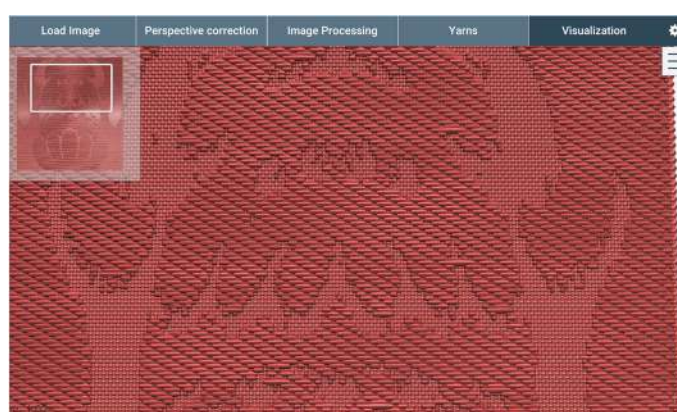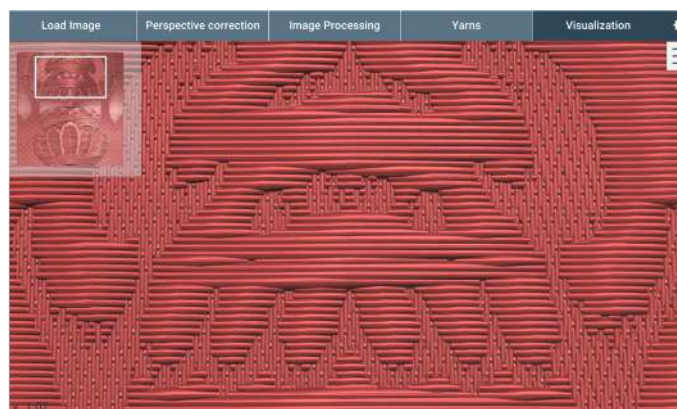

Figure 2. Selection of a weaving technique in the Virtual Loom.

(**a**)

(**b**)

(**c**)

**Figure 3.** Examples of 3D representations for the same input image, using only two zones, recreating three different weaving techniques: (**a**) damask; (**b**) lampas; (**c**) espolín.
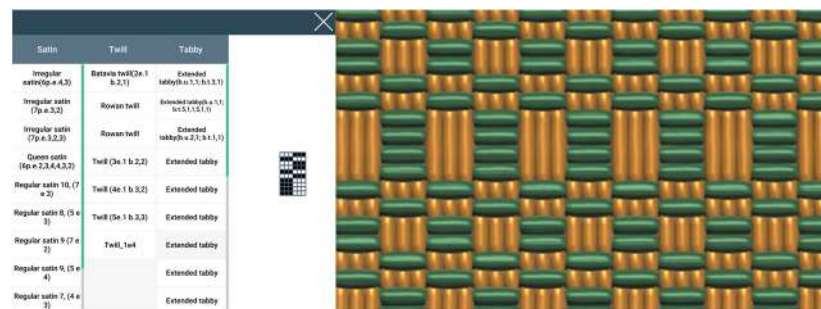
Functionality F04. Selecting the Yarn tab of the Virtual Loom, the user can choose a weave with the "weave" button. The set of weaves made available to the user depends on the selected weaving technique. Figure 4 shows the effects of applying different weaves on the resulting 3D model.
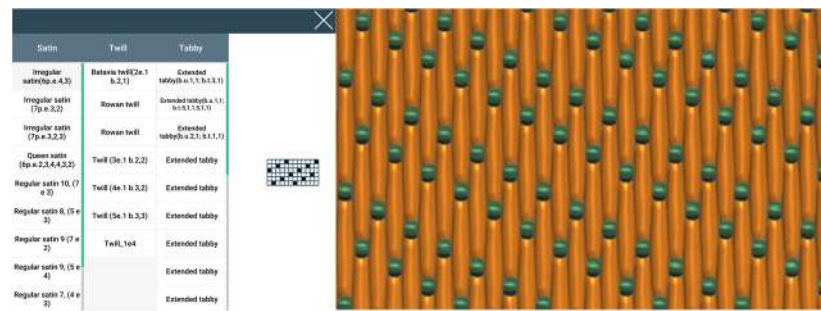
(**a**)

(**b**)

(**c**)

Figure 4. Examples of applying different weaves in the Virtual Loom: (**a**) an irregular satin weave; (**b**) a twill weave; (**c**) an extended tabby weave.

Functionality F06. In the Image Processing tab, the number of yarns, each corresponding to a color, can be adjusted using a dropdown menu (Figure 5). The number of colors that can be selected depends on the selected weaving technique. For instance, for damask, only two colors can be selected, as this technique involves only two yarns in the weaving process.
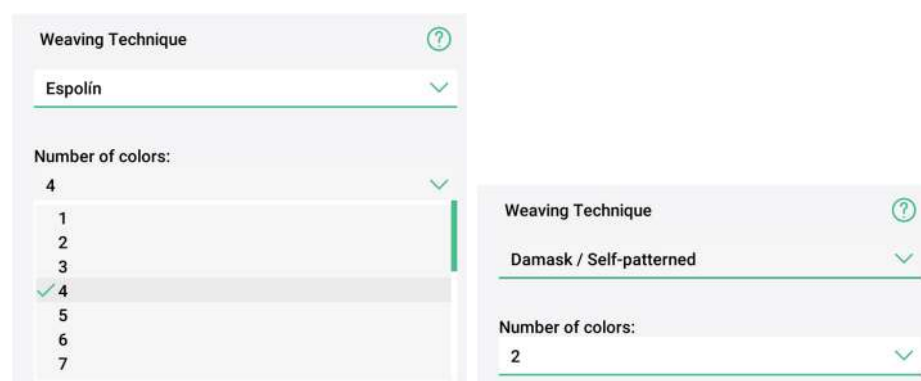
Figure 5. Examples of selecting the number of colors, depending on the weaving technique.

ADASilk [18] integrates an exploratory search engine and a spatiotemporal map. It is built on top of SILKNOW's knowledge graph, which contains nearly 40,000 fabric entries with images and other relevant information (production place, production timespan, material, technique, etc.). This information is enriched by text analysis tools that automatically extract data from the description of the fabrics. The functionalities related to ADASilk, and the related personas and sectors, are shown in Table 2. Examples F04 and F09 are detailed afterwards.

Table 2. List of the functionalities that ADASilk fulfills and their relation to personas and sectors.

General Functionality	Func. ID	Description of the Functionality (Additional Comments)	Personas	Sectors
Having access to a more personalized experience	F01	Having a personal account	All	All
	F02	Being able to save favorite images and share a personal selection of items, like a curated exhibition	All	Research and education
	F03	Using an advanced search interface and filtering results according to historical period and/or geographical origin	Visitor; Fan of fashion; Student in textile history; Fashion journalist	Cultural heritage and leisure; Research and education
	F04	Using an advanced search interface and filtering results according to weaving techniques and fabrics	Museum director; Student in textile history	Cultural heritage and leisure; Research and education
	F05	Using an advanced search interface and filtering results sccording to motifs, decorative patterns	Museum director; Student in textile history	Cultural heritage and leisure; Research and education
Finding and visualizing	F06	Browsing the results grouped by visual similarity among the textiles	Museum director; Student in textile history	Cultural heritage and leisure; Research and education
	F07	Having access to the name of the owning institution in the record and being able to click on their name for more information (location, contacts…)	Museum director; Student in textile history	Cultural heritage and leisure; Research and education
	F08	Having access to the names of the authors of the record and the collection	Museum director;	Cultural heritage and

		curators' names (when available in the records)	Student in textile history	leisure; Research and education
	F09	Clicking on a weaving technique in order to access a detailed analysis of it in the Virtual Loom, when available	Museum director; Textile designer	Cultural heritage and leisure; creative industries
Downloading	F10	Querying our database through an API, not just through a web interface	Museum curator	Cultural heritage and leisure
	F11	Downloading a list of selected results with a standard, basic set of metadata	Museum curator	Cultural heritage and leisure
	F12	Downloading individual search results (one record) in the format chosen by the user	Visitor; Conservator; Textile designer	Cultural heritage and leisure; creative industries

Functionality F04. The user has many filters to apply and reduce results among the more than 40,000 records available in ADASilk. For instance, the advanced search interface can be used to filter results by facets. Figure 6 shows 399 results after applying "gold thread" as material and "brocatelle" as weaving technique.
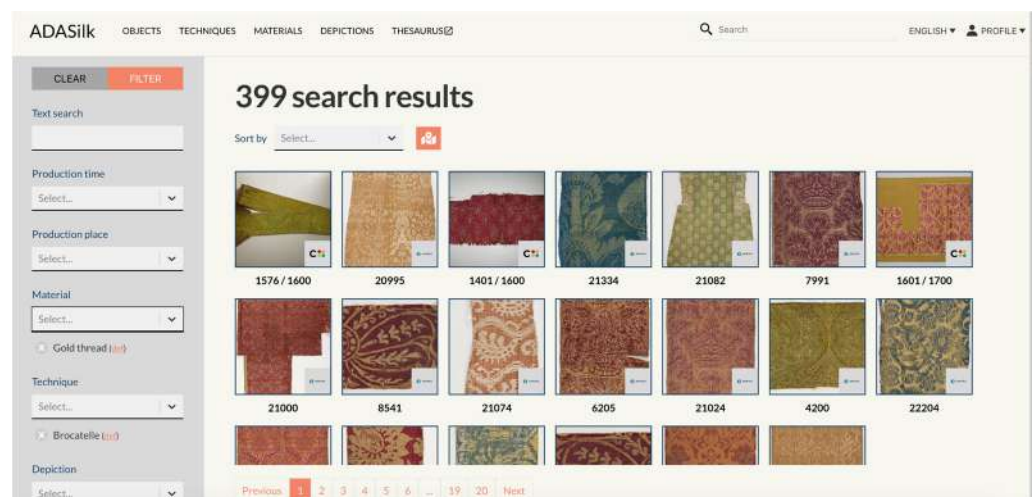
Figure 6. Results on ADASilk after selecting filters.

Functionality F07. Having access to the name of the owning institution in the record and being able to click on their name for more information. Here, users can read what the museum wrote in their catalog records about the selected image and can directly access the museum's database or ask for further information. Figure 7 shows a record from the Spanish National Museum database.
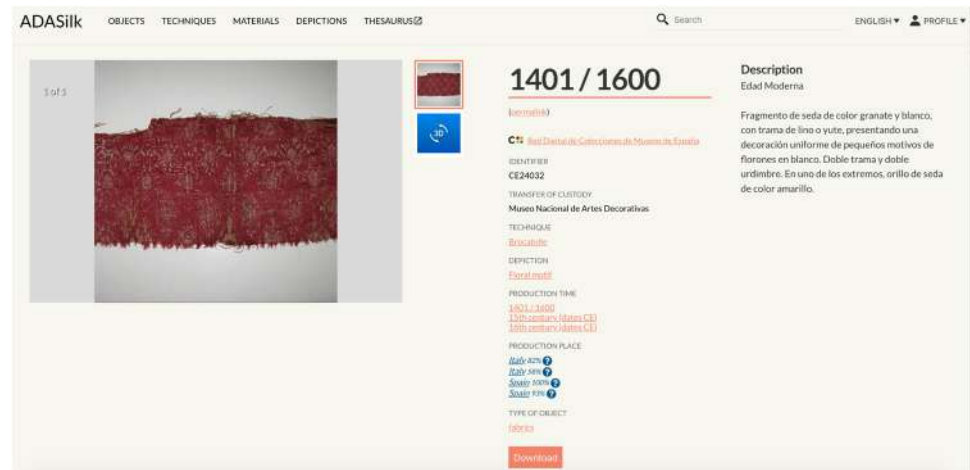
Figure 7. Brocatelle no CE24032 from CERES, the Spanish National Museum Database.

These tools developed under the SILKNOW project were tested on the Piraino collection, as shown in the following sections.

4. Bringing SILKNOW's Tools to a Sicilian Museum

In this section, we illustrate how the technologies developed in the SILKNOW project were used by Professor Raffaello Piraino, the director of a historical clothing collection in Palermo (Figure 8).

As a first step, we explained to him how the tools included in SILKNOW work, specifically, the Virtual Loom and ADASilk. The curated catalog of his 1250 collection items is stored on the museum computer and can be accessed through a simple database interface that provides only the ability to perform simple queries. Therefore, access to this impressive collection can be improved by using SILKNOW tools as the search functionalities in ADASilk are richer, visually similar objects can be found, and a 3D representation of the fabric designs is possible.

Figure 8. Professor Piraino interacting with the Virtual Loom.

In Figure 9, details of some of the fabrics can be seen; some are in good condition, but others are somewhat worn. It was interesting to note that the Virtual Loom provides the ability to create a 3D reconstruction even of a partially damaged fabric or from incomplete images. In this way, fabric can be virtually restored to its original state and examined for various purposes, including its materialization with a 3D printer.

Figure 9. Details of some fabrics.

After the training session with Prof. Piraino, a number of considerations arose from the experience with ADASilk and the Virtual Loom:

- From the point of view of usability, both ADASilk and the Virtual Loom were easy and straightforward for the user, who learned to use the tools immediately. This was fairly simple, as the user in question had already mastered all the specialized terms and concepts behind the designs, e.g., fabric types, weft, warp, and different weaving techniques. One could say that the use of the tools was almost instinctive. For instance, in the search for similar images, the user immediately recognized what he was interested in and was able to make considerations about floral patterns based on the elements displayed and relate the different periods, the prevailing influences for each period, etc.
- From a technical point of view, the user found that for the Virtual Loom to be even more fruitful, the loaded images must be gathered in specific ways, taking special care of the incident light. Some photographs can become practically unusable because the original image has a different brightness space due to the reflection of light on the fabric. This prevents a faithful 3D reconstruction of the top of the photographed piece of fabric (Figure 10). Thus, as an experienced user in his field, after his initial use of the tool, he was able to determine how the images in the collection should be created for proper and efficient 3D reconstruction in the Virtual Loom.

Adding a symmetrical piece of a textile, if the design has a symmetrical axis, is a functionality for reconstructing partially damaged fabrics or incomplete images [16].

- Another consideration is that, although Prof. Piraino reported that he was not an experienced user of computers and information technology, he could easily derive the 3D models and quickly learn about the strengths and limitations of the tool regarding the images that can be properly processed. He performed more trials on images of items from his catalog with good results, as shown in Figure 11.
- Finally, Prof. Piraino commented that the tools were very suitable for enriching silk textiles collections (Figure 12), improving their dissemination and people's understanding.
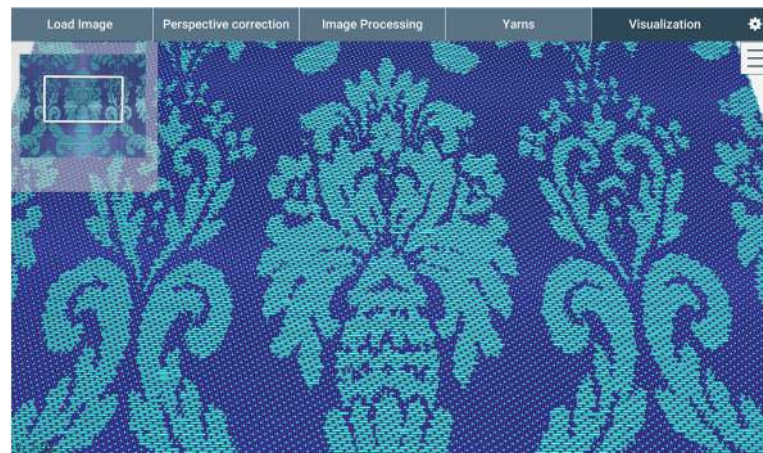

(**a**)

(**b**)
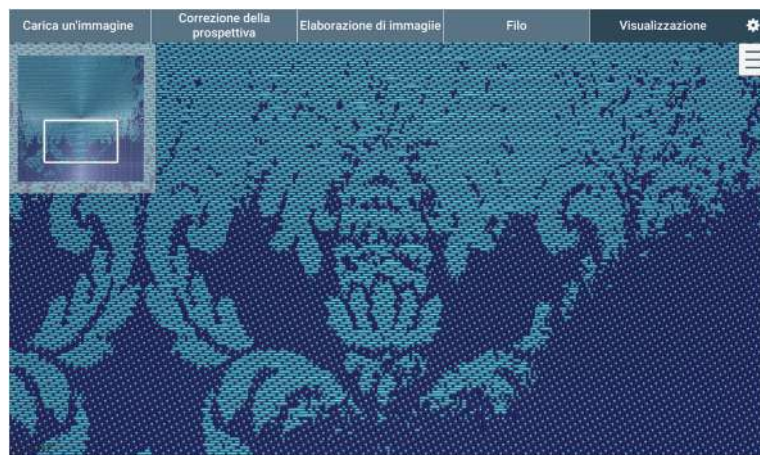
(**c**)

Figure 10. Using the Virtual Loom with a non-optimal image: (**a**) selection of the area of the image; (**b**) selection of the yarns and colors to represent the ground and the pictorial part; (**c**) Resulting 3D model.
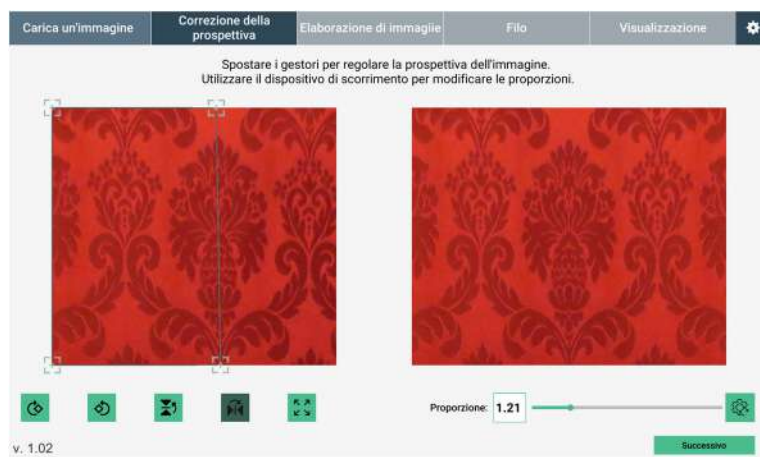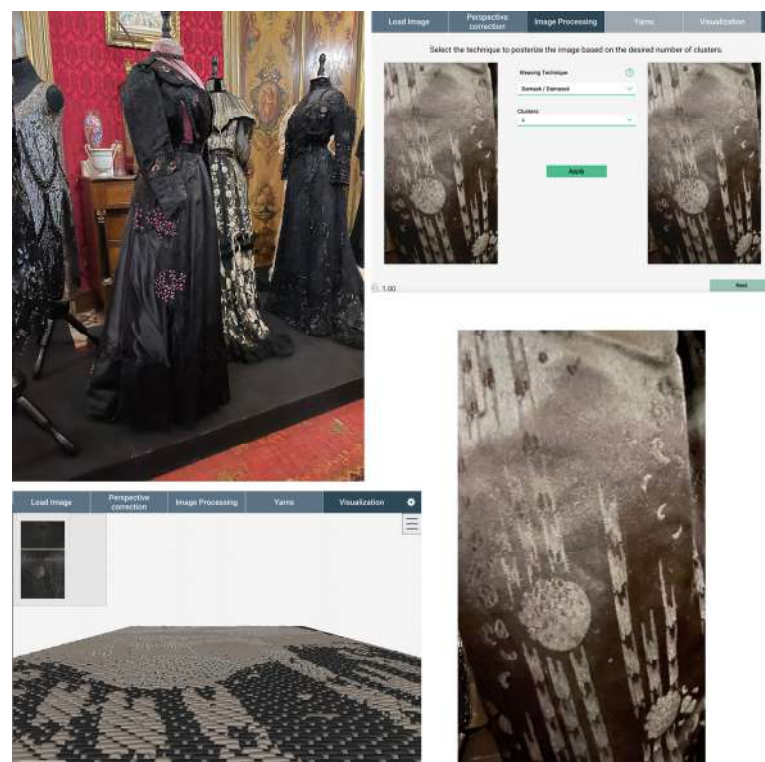

(**a**)
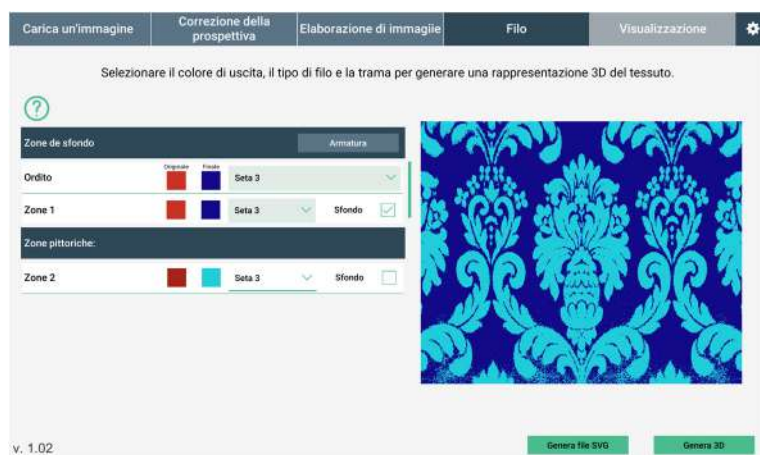
(**b**)

(**c**)

Figure 11. Using the Virtual Loom with an optimal input image: (**a**) selection of the area of the image; (**b**) selection of the yarns and colors to represent the ground and the pictorial part; (**c**) Resulting 3D model.

Figure 12. Example of a dress and a 3D reconstruction of a portion of its design.

5. Making Museum Cataloged Data Compatible with SILKNOW's Search Engine: Future Steps for the Piraino Collection

Adding the Piraino collection to ADASilk will imply connecting it with more than 40,000 related assets. This will entail worldwide accessibility and its possible use for better cataloging as it will help to find new connections among similar fabrics.

In this sense, transferring silk fabric collections to SILKNOW's knowledge graph is a simple process consisting of three main steps:
1. The creation of a dataset for each artifact;
2. The insertion of the datasets into the knowledge graph and their semantic mapping;

3. Binding and visualization through ADASilk.

The same process can be applied to any type of object or museum collection. In fact, during the development of the SILKNOW project, a web application (available as a desktop version) was developed for the input of all data related to an object. The interface of the application traces the record fields as they were defined during the project, after extensive consultation among experts from different fields.

The CIETA cataloging standard was used as a reference, and the following fields were included in the application: identification number, a formal description of the artifact, type of weaving technique, manufacture, chronological location, dimensions, storage location at the time of cataloging, and inventory number, as well as stylistic annotations.

In this way, the application allows the creation of a record that is simplified in content, but still contains all the basic information needed to identify a textile artifact. In particular, the "Notes" field allows ADASilk's intelligent search engine to link the artifact to other similar artifacts. The stylistic notes contain decorative modules to better identify the uniqueness of the artifact. The notes are accompanied by a bibliography, if the artifact is unpublished, and photographs taken at the site where the artifact was found. The resulting dataset is then converted to a JSON file and imported into the Knowledge Graph. The main advantage in using this application is the simplicity and speed with which museum collections can be cataloged, as shown in Figure 13.

Figure 13. The interface for adding records to SILKNOW.

As previously mentioned, we already took the first steps to transfer the Piraino collection into ADASilk. We hope that the work undertaken with this collection might encourage others to use the SILKNOW tools and open up their collections.

6. Discussion and Conclusions

Museums, traditionally charged with the task of preserving the memory of the past, are facing their digital transformation by making information accessible and understandable for current citizens.

As a case study for this kind of process, we have presented some of SILKNOW's results. Far from offering a traditional look at museum collections, the Virtual Loom experience is shown as a laboratory of innovation and creativity, linked to the present [49]. This tool allows the preservation, protection, and dissemination of the legacies of textiles (specifically silk), of their history, evolution, designs and different weaving techniques. At the same time, it offers a door towards the future through the enhancement of the collections' information and dissemination. This should provide an impetus for the preservation of the living heritage still present in the silk industries, as well as in small and medium-sized museums that are witnesses to our history [19]. Ensuring the usability and usefulness of the designed tools required an extensive joint effort with professionals from the textile sector. This facilitated their interest in the tool for their daily work, now and in the future [50,51].

Furthermore, the fact that we have taken the first steps to integrate this collection into ADASilk facilitates its entrance to the digital arena. As the growing number of cases and examples in the literature shows, small and medium-sized institutions have adopted some schemes of digitization, open access, and interoperability for the information about their holdings [52]. These shared repositories ensure the practice of better cataloging and information management strategies while allowing them to increase their visibility. As mentioned, despite keeping some of the most important Sicilian clothing, the Piraino collection was not widely known. Making it easy to transfer data to the SILKNOW repository is already a major step that will guarantee a permanent exercise of access to Sicilian culture while helping to connect it with similar collections. The skills developed by interdisciplinary research can generate specific applications in the fields of design, industry, and technology in terms of the use of sustainable materials, research, and the development of innovative processes for product research and market development.

Additionally, we have addressed the importance of museum accessibility both by preparing user scenarios before dealing with the creation of digital tools, and by applying SILKNOW tools to a real scenario. Predefined personas allowed ICT developers to have concrete and visual representations of targeted end users at their disposal, helping them to understand their needs and expectations. Linking these experiences to the physical environment has demonstrated how they can be designed to better support cultural heritage institutions [53]. The results of our work with the Piraino collection show how useful it is to have in mind a user scenario before addressing the challenges of developing digital tools for cultural heritage safeguarding.

Finally, this experience is easily applicable to any museum, regardless of its size and staff (aim 3). The fact that these are open access tools, within the reach of any institution, facilitates their application, especially in those museums that, due to a lack of staff and economic resources, have difficulty making their collections known. In this sense, thanks to the workshops carried out by the project and the experience with this collection, more Sicilian museums are joining in the application of these tools.

Silk heritage has played a major role in building today's Europe. Despite this, it is insufficiently recognized as an important kind of cultural heritage of both a tangible and intangible nature. Moreover, its conservation is a very complicated task, given the physical fragility of silk and its dispersion in many small institutions. The results shown in this article demonstrate how small and medium-sized museums can access tools that will help them to carry out their daily tasks. ICOM states that the museum must be able not only to conserve the cultural property it holds, but also to give the public access to this property [54]. SILKNOW has responded to this mandate, thus becoming an element of support for textile museums.

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